

Development of an  
Anti-Coincidence Detector for the  
X-ray Microcalorimeter Spectrometer  
onboard the  
International X-ray Observatory

C.N. Bailey

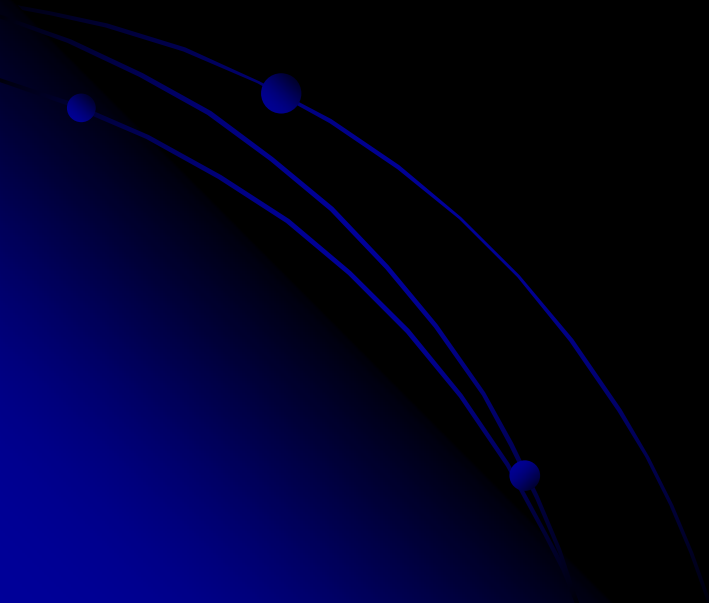
CERCA

November 21, 2008



# Outline

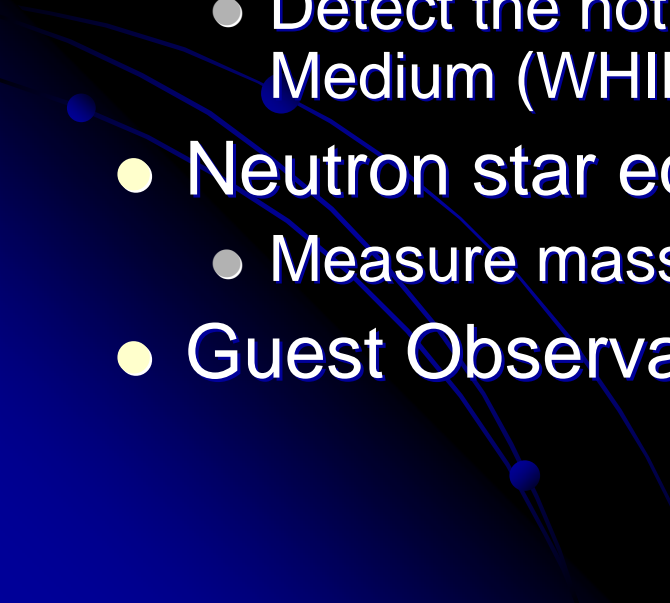
- International X-ray Observatory
- X-ray Microcalorimeter Spectrometer
- Cosmic Ray Backgrounds
- Anti-coincidence Detector



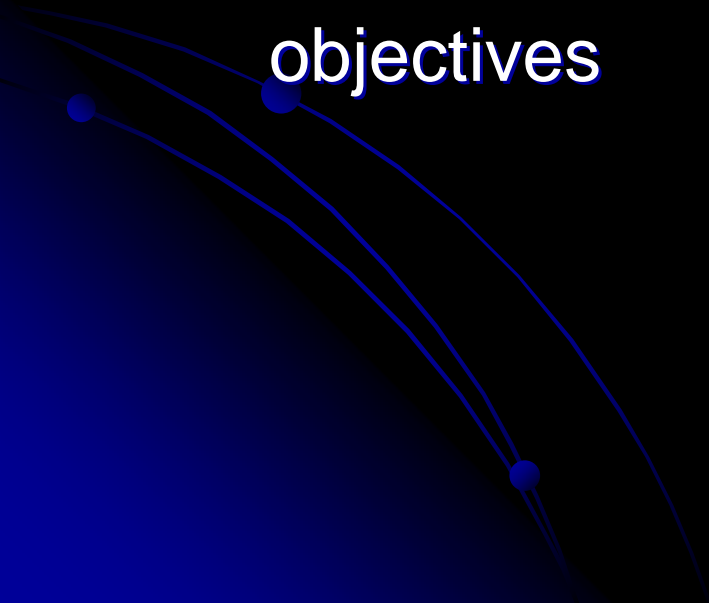
# International X-ray Observatory (IXO)

- X-ray observatory dedicated to high resolution x-ray spectroscopy
- Consists of 4 x-ray telescopes on the spacecraft, each with a 10 m focal length and 1.3 m diameter
- Located in the L2 Lagrange point orbit (same as WMAP)
- Formerly known as Constellation-X
- Joint ESA, NASA, JAXA mission

# IXO science

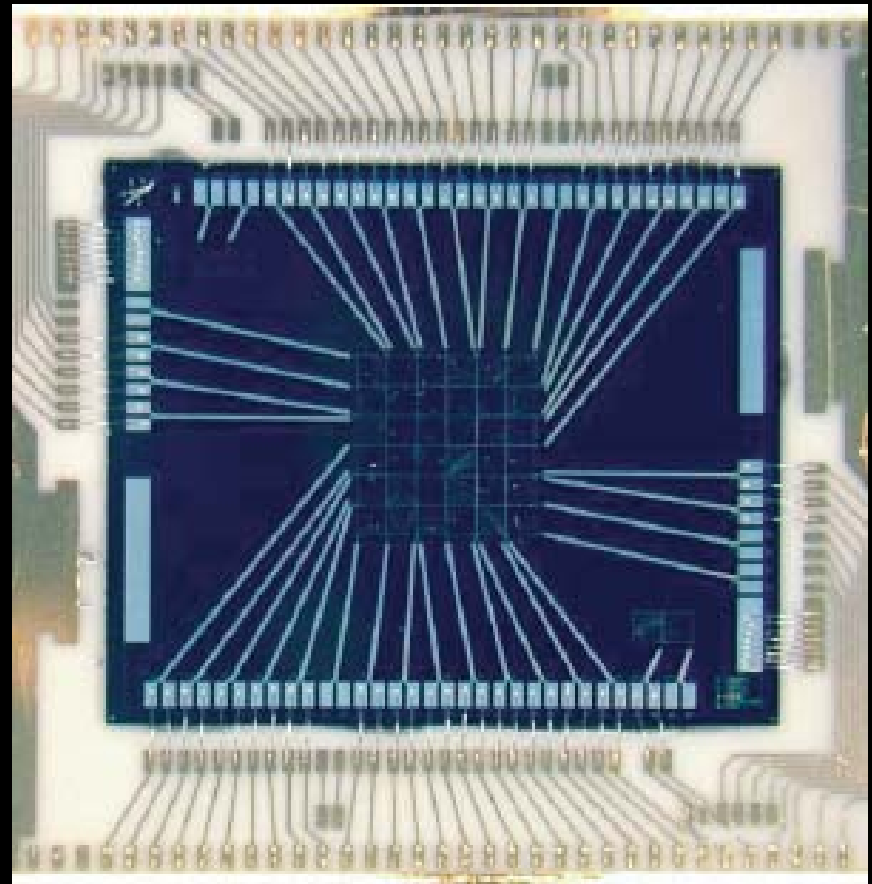
- Black holes
    - Test General Relativity & measure black hole spin
  - Dark energy
    - Improve constraints on dark energy parameters
  - Missing baryons
    - Detect the hot phase of the Warm-Hot Intergalactic Medium (WHIM) at  $z > 0$
  - Neutron star equation of state
    - Measure mass-radius relation
  - Guest Observatory
- 

# X-ray signal

- Energies between 0.1 - 10 keV
    - Able to see the inner (K-shell) lines for all of the abundant metals
    - Need high resolution spectroscopy in order to resolve the lines and achieve the science objectives
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# X-ray Microcalorimeter Spectrometer (XMS)

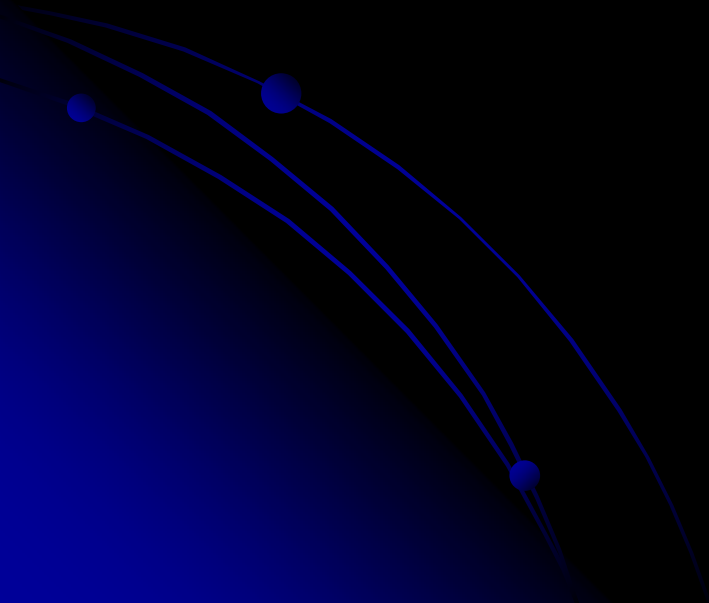
- One of three core instruments for the x-ray data collection from the IXO telescope
- Contains ~ 2000 Mo /Au bilayer TES coupled to Au / Bi absorbers



Suzaku/XRS array

# XMS Backgrounds

- Cosmic X-ray background (primarily due to unresolved point sources at high energies)
- Particles from the sun
- Cosmic Rays



# Cosmic Ray Background

- Signal

- X-ray sources of interest have fluxes as low as  $2 \times 10^{-15}$  erg / cm<sup>2</sup>-s
- IXO telescope effective area (at 1 keV) = 15,000 cm<sup>2</sup> with a 5 arcsec resolution
- One 0.3 mm XMS pixel covers 3 arcsec

-  count rate can be as low as ~ 0.01 photons / s

- Cosmic Ray Background

- At L2 orbit, cosmic ray flux (w/ energy > 1 MeV) ~ 6 events / cm<sup>2</sup>-s

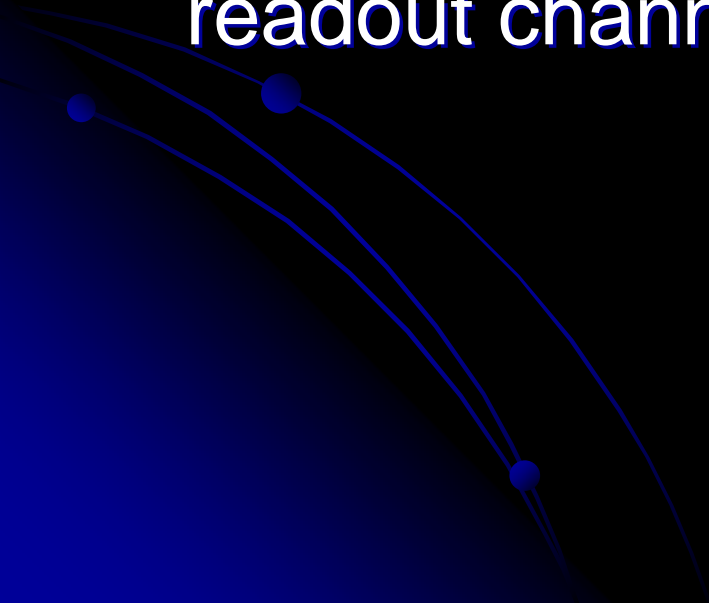
-  equivalent count rate in XMS of 0.02 counts / s

# Cosmic Ray Backgrounds II

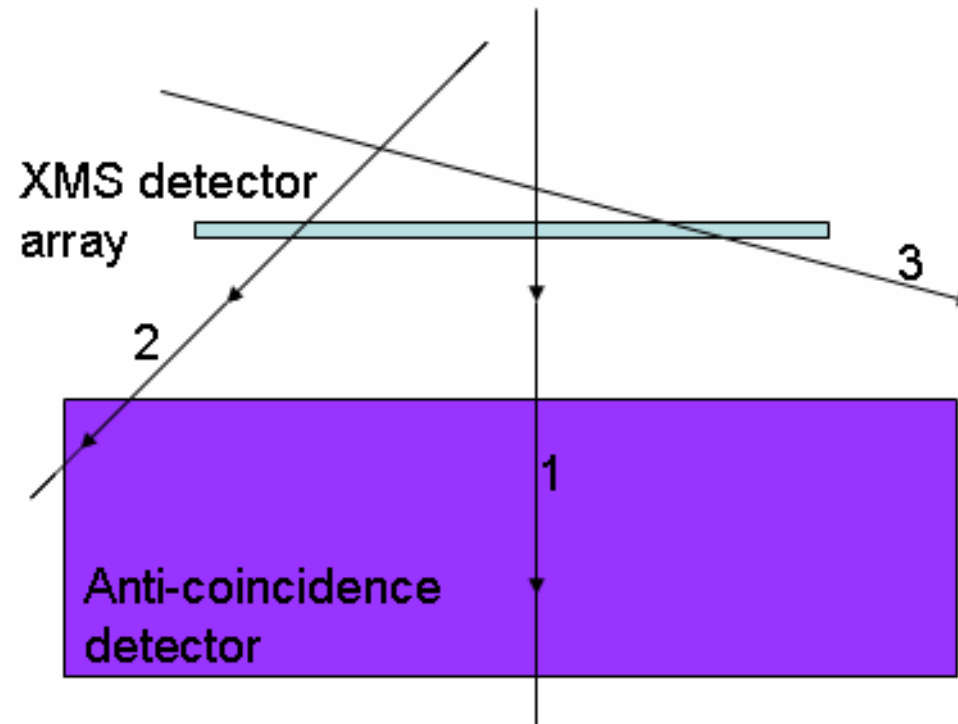
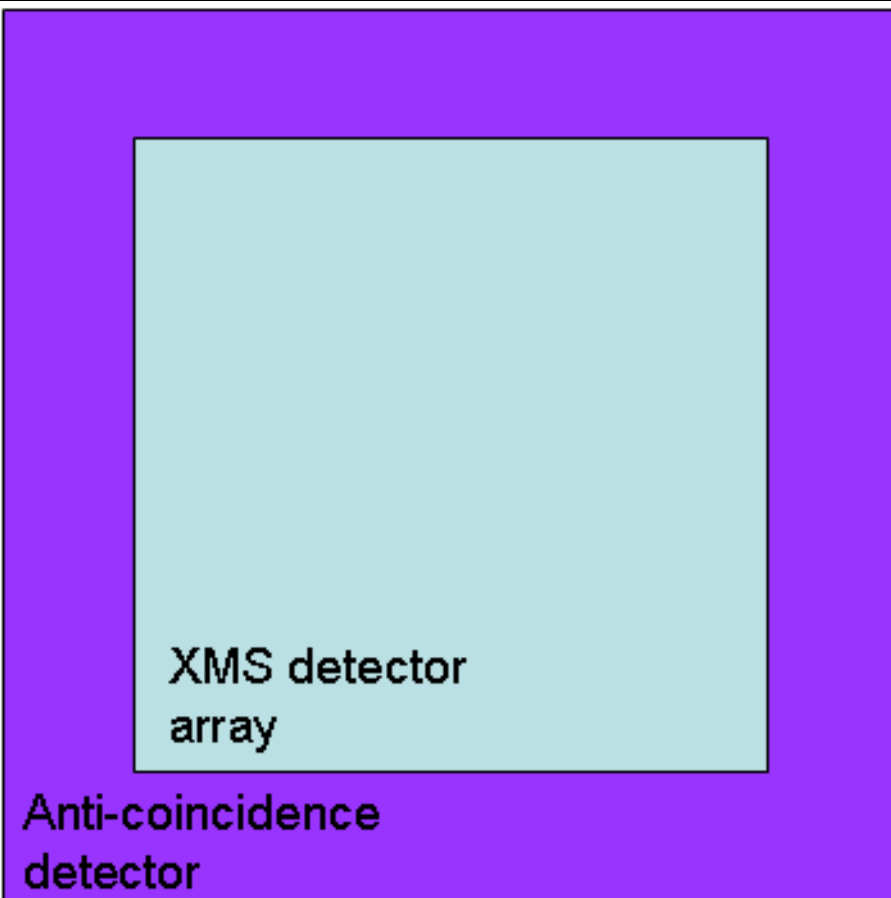
- Cosmic rays with energies above  $\sim 100$  MeV
  - Interacts in matter and enter the minimum ionizing regime
  - Minimum ionizing particles (MIPs) are very penetrating
  - Energy deposited by a MIP is independent of its energy, but proportional to the path length traveled
- Cosmic rays with energies below 10s of MeV
  - Largely be stopped in the IXO satellite and material surrounding the XMS detector
  - Secondary particles such as electrons & gamma-rays that Compton scatter in the calorimeter can mimic x-ray signal

# XMS Anti-coincidence Detector

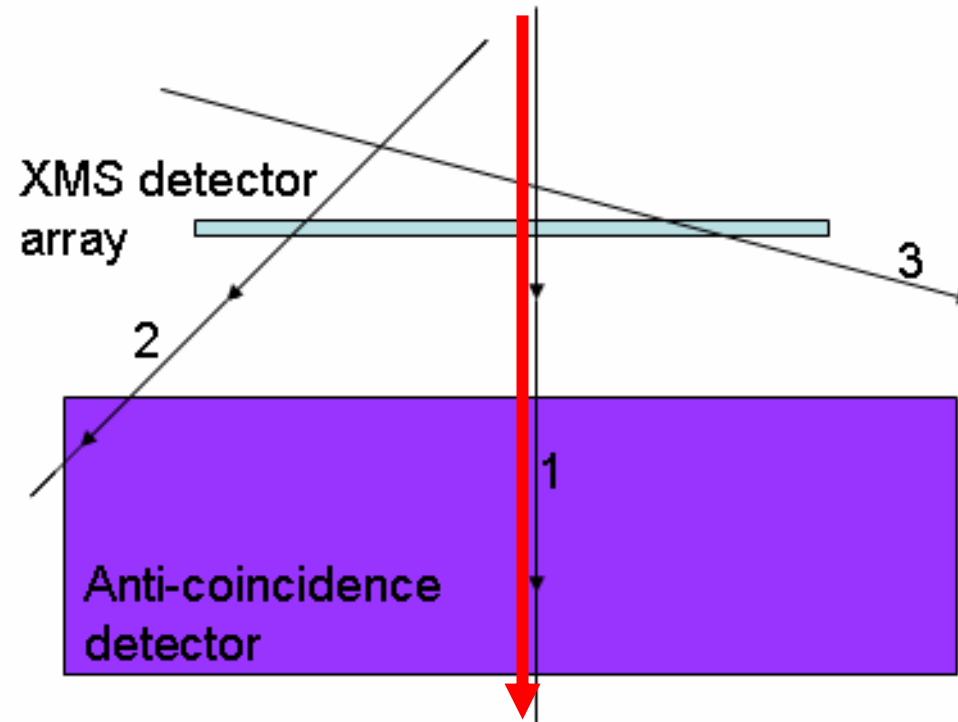
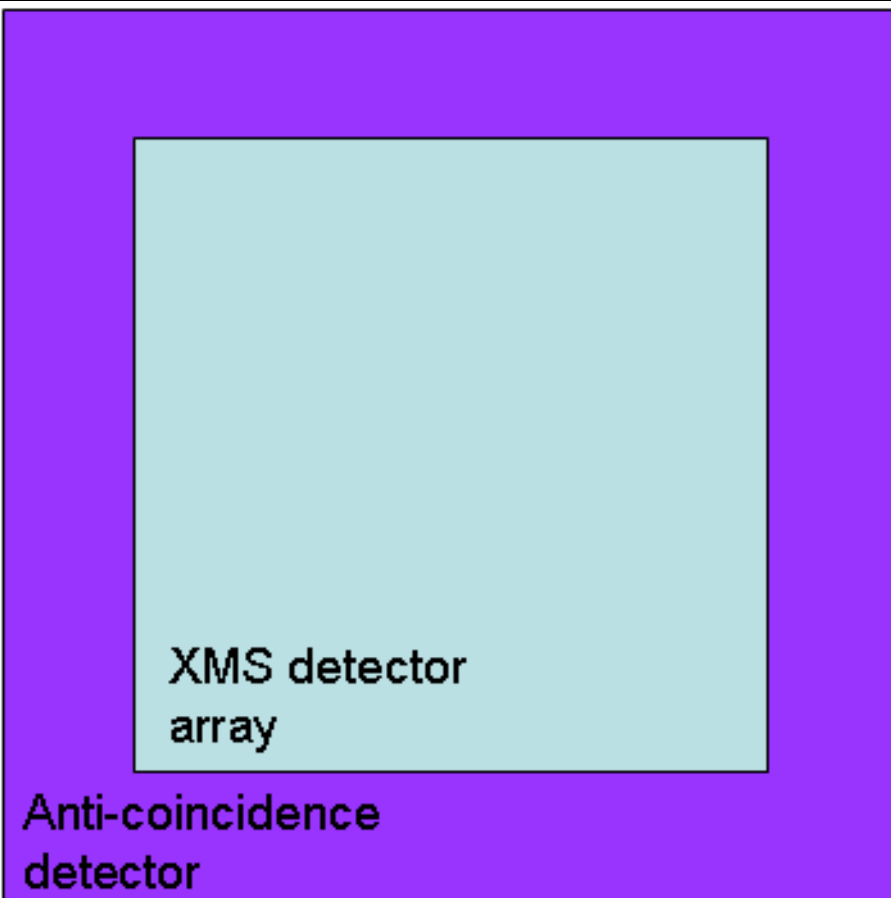
- Maximize x-ray signal to cosmic ray background noise
- Readout that is compatible using SQUIDs
- Large area with a minimal number of readout channels



# Example Anti-co geometry

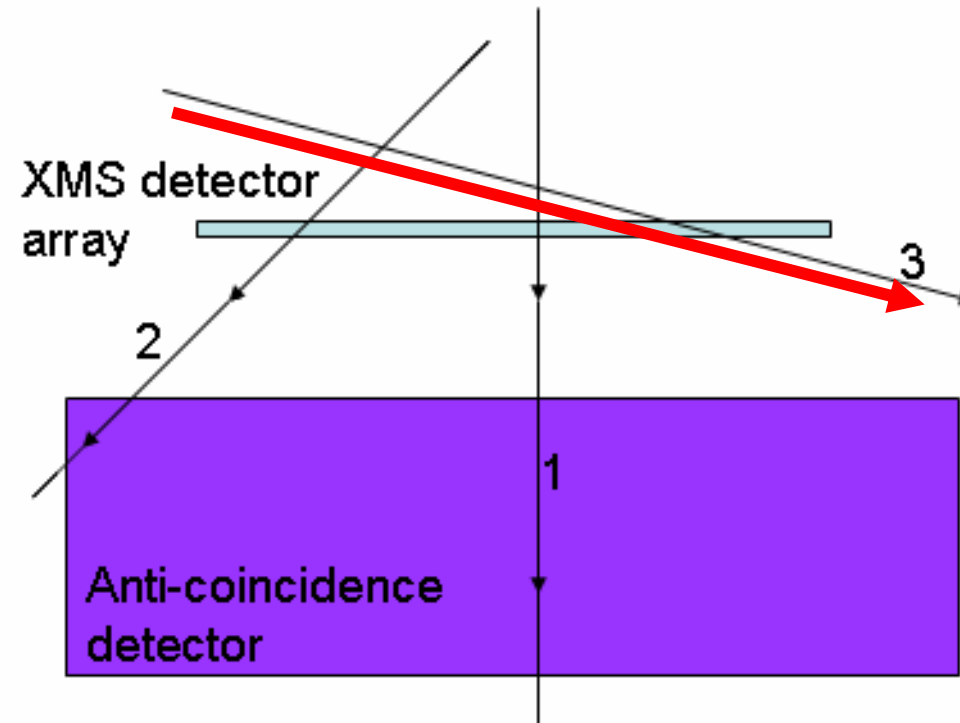
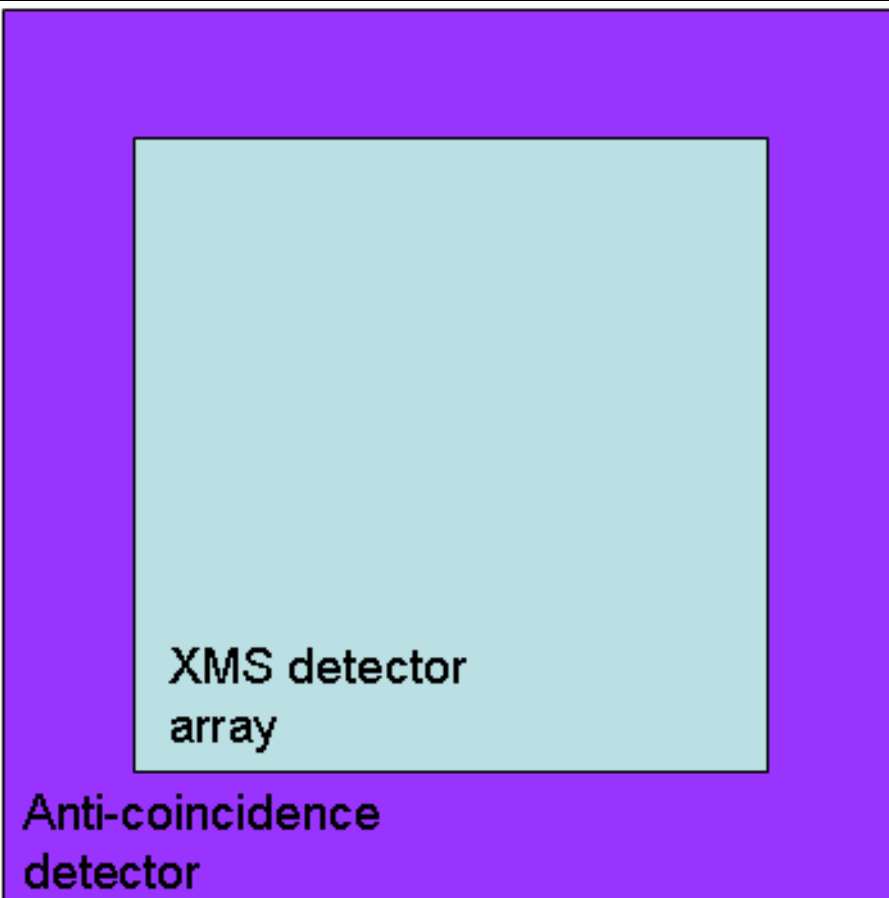


# Example Anti-co geometry



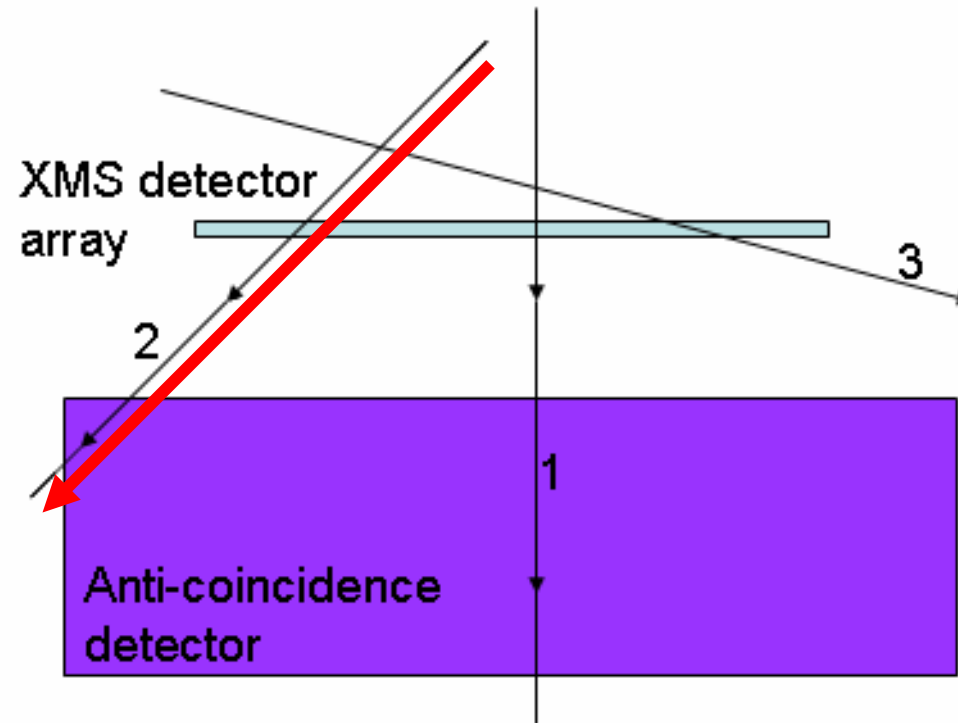
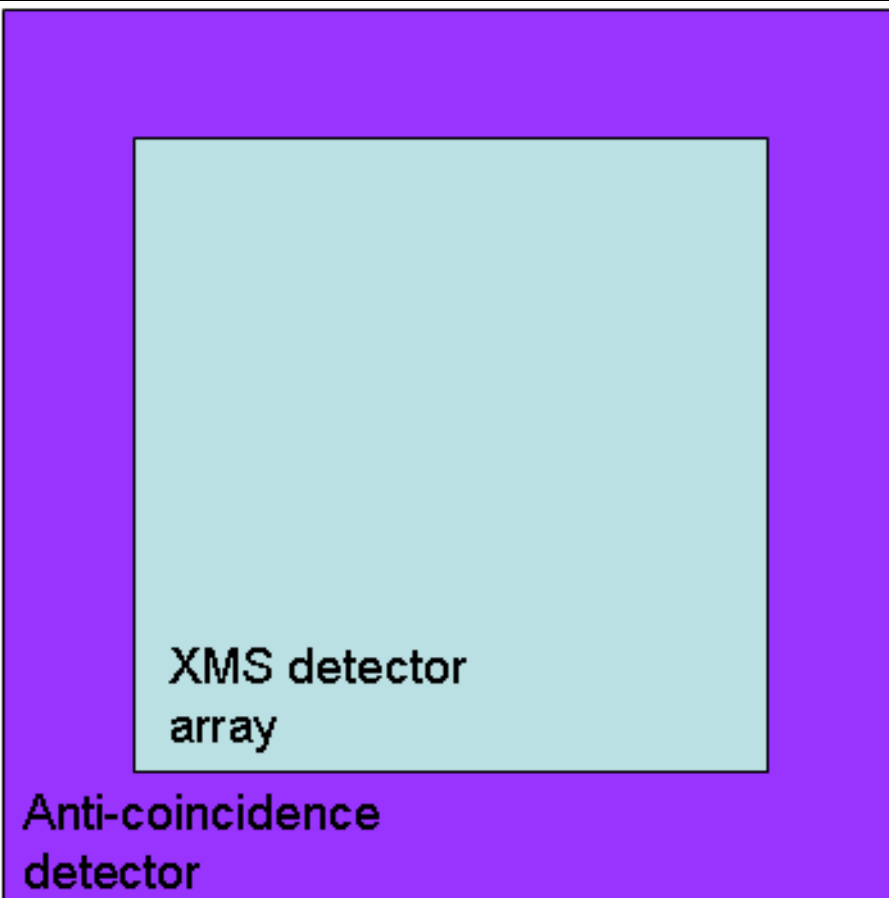
- MIP traveling along path #1
  - Deposit ~ 6 keV into XMS (least energy of any path)
  - Deposit ~ 195 keV into a 0.5 mm Si anti-co detector

# Example Anti-co geometry



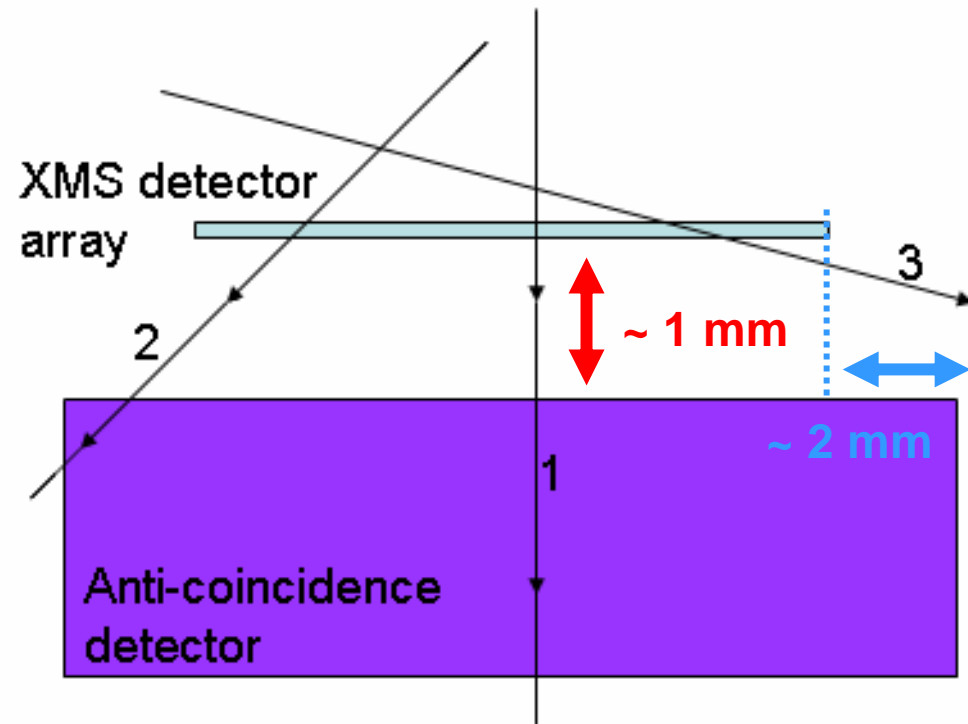
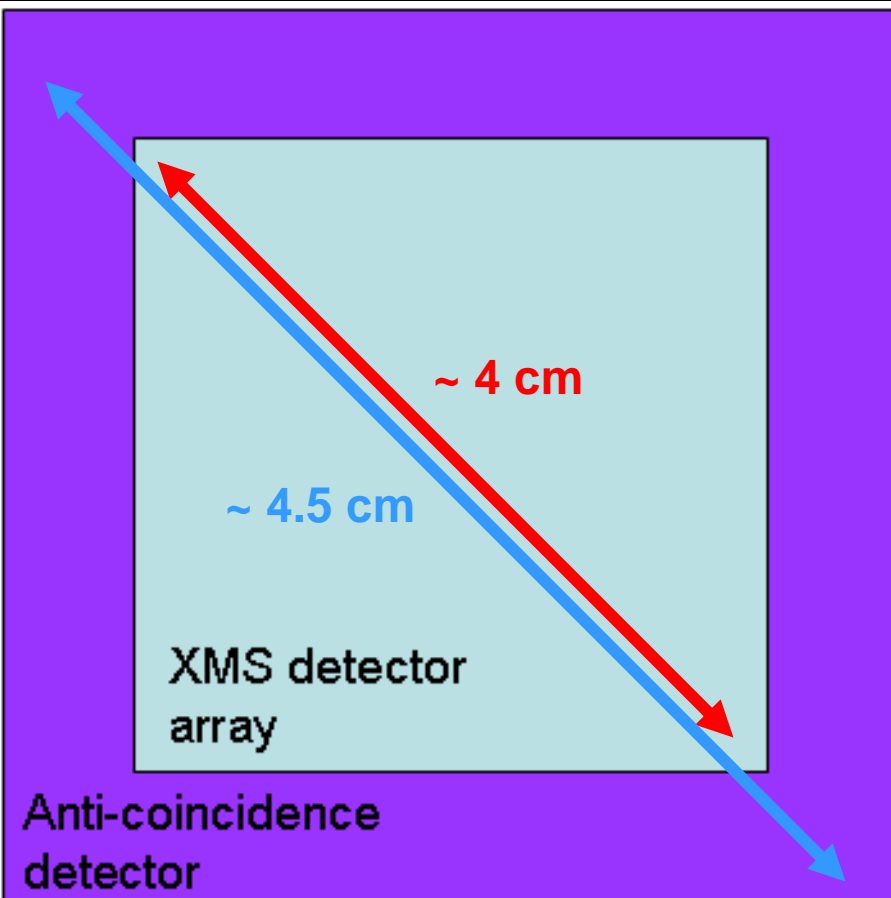
- MIP traveling along path #3
  - Deposit more energy than the upper threshold of the XMS detector
  - Rejected regardless of an interaction in the anti-co detector

# Example Anti-co geometry



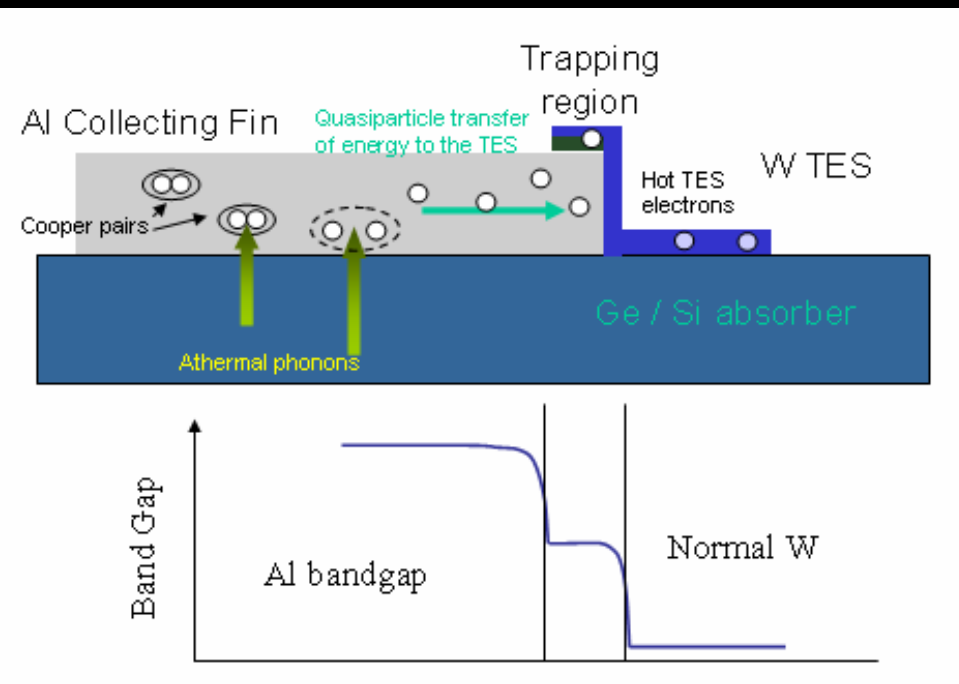
- MIP traveling along path #2
  - Deposit energy into the XMS detector equal to the upper signal threshold
  - To be vetoed, needs to deposit enough energy in the anti-co detector

# Example Anti-co geometry



- Assume a XMS upper threshold ~ 12 keV
- Assume a 20 keV trigger for anti-co detector

# Possible Anti-co sensor



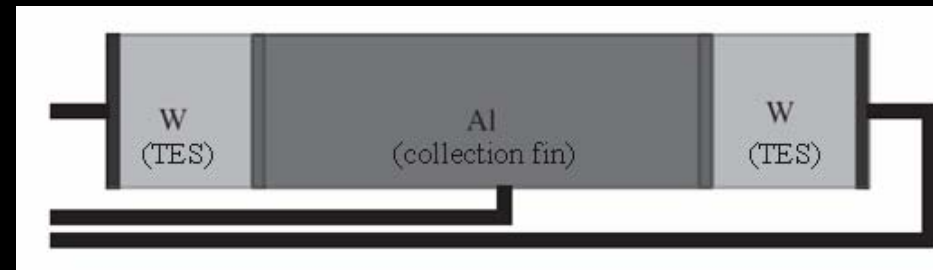
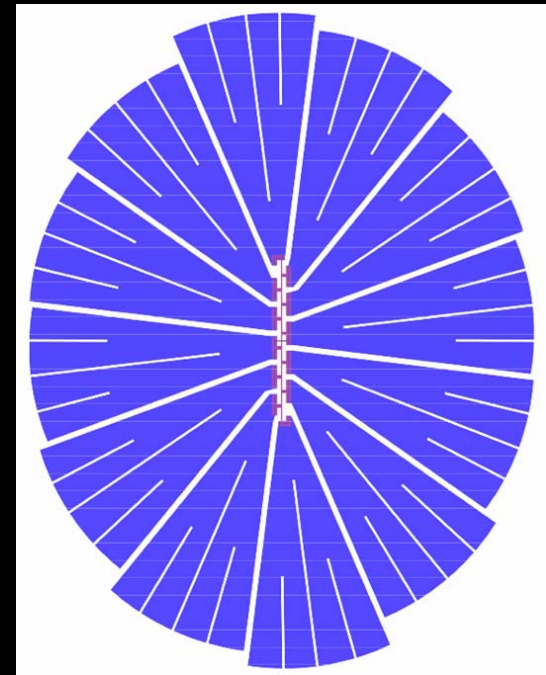
- Mimic CDMS phonon collection system
- Many TES in parallel
- TES connected to phonon collection 'fins' to increase active collection area

# Questions / Ideas...

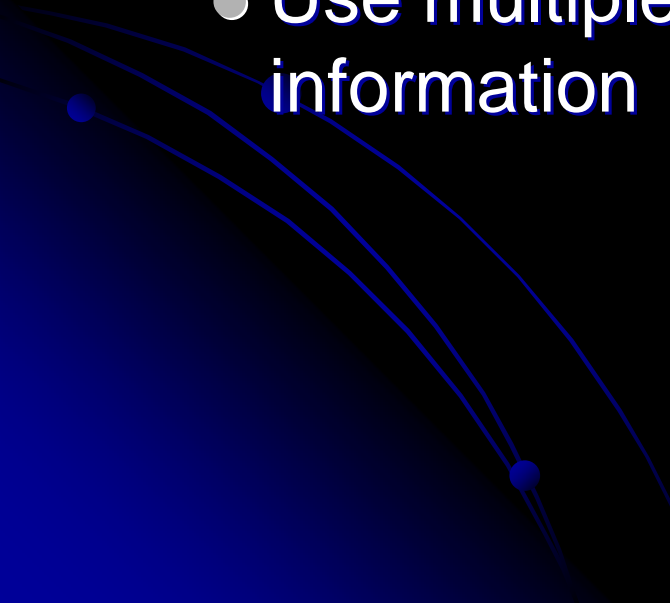
- What materials & material properties are most suited for the anti-co detector?
- What geometry should the anti-co phonon collection system have?
- What geometry should the anti-co detector have?
  - How many channels?
  - What orientation?
- How to physically mount and heat sink the anti-co detector to the cryostat?

# Materials / Geometry of phonon collection system

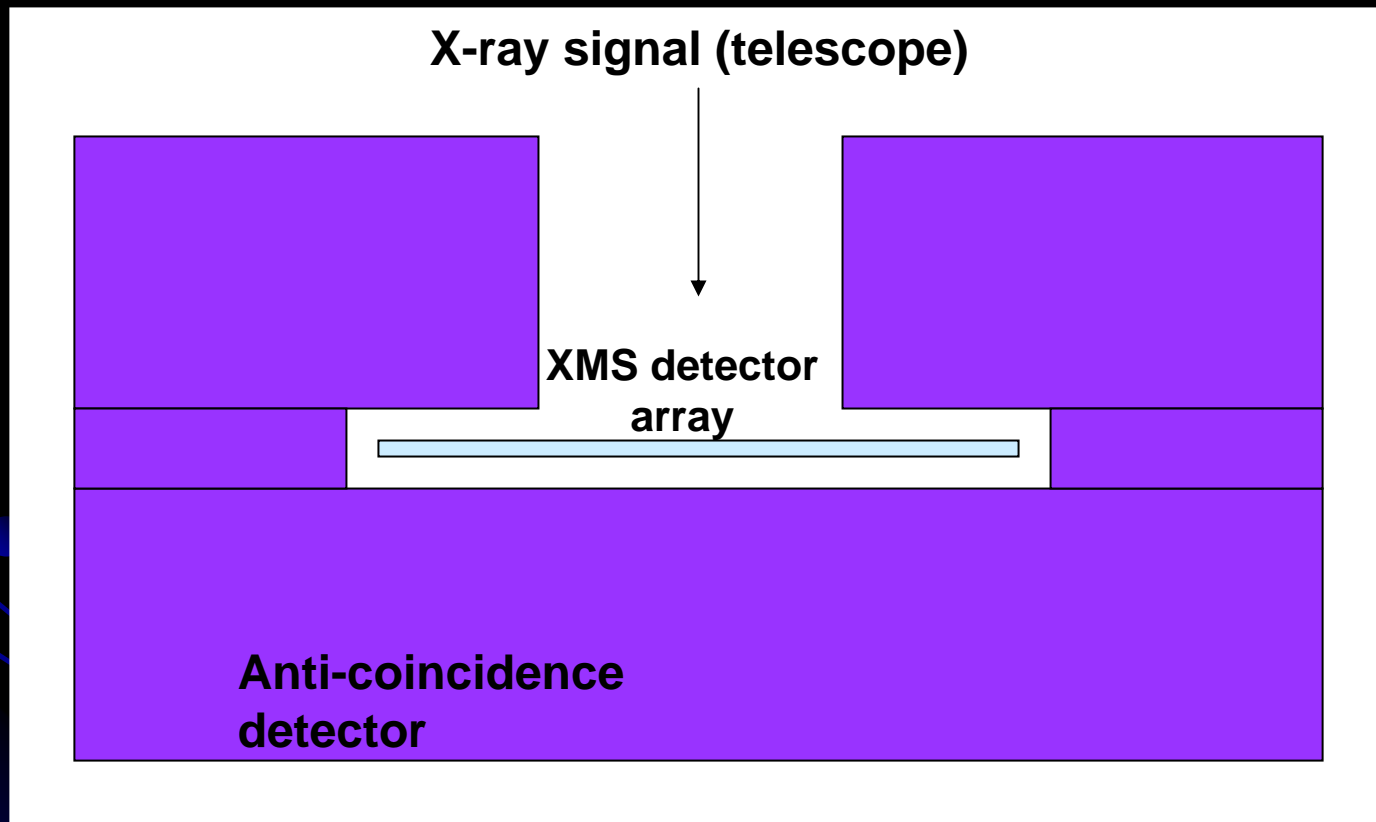
- Materials
  - W and Al?
- Geometry
  - Maximize surface area coverage & collection efficiency
  - Determine optimal length of phonon collection fins (balance quasiparticle diffusion & electron-phonon coupling of TES to substrate)



# Geometry of Anti-co

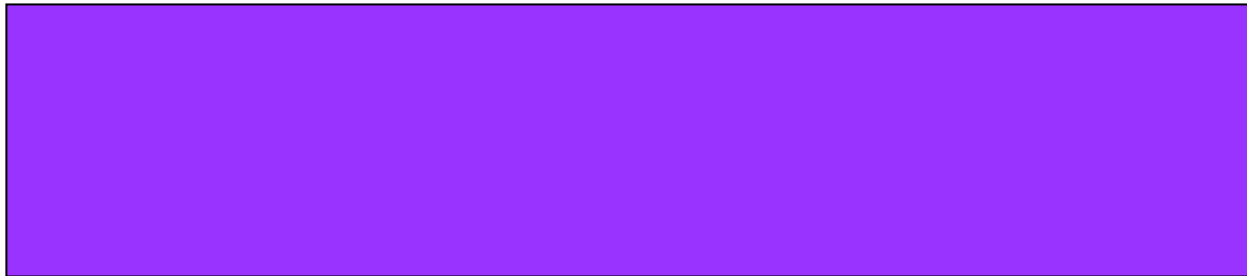
- Can we differentiate cosmic ray primaries from secondaries?
    - Surround XMS on all sides with anti-co
    - Stack multiple anti-co detectors under XMS
    - Use multiple readout channels to get position information
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# Surround XMS




# Stack under XMS

XMS detector  
array



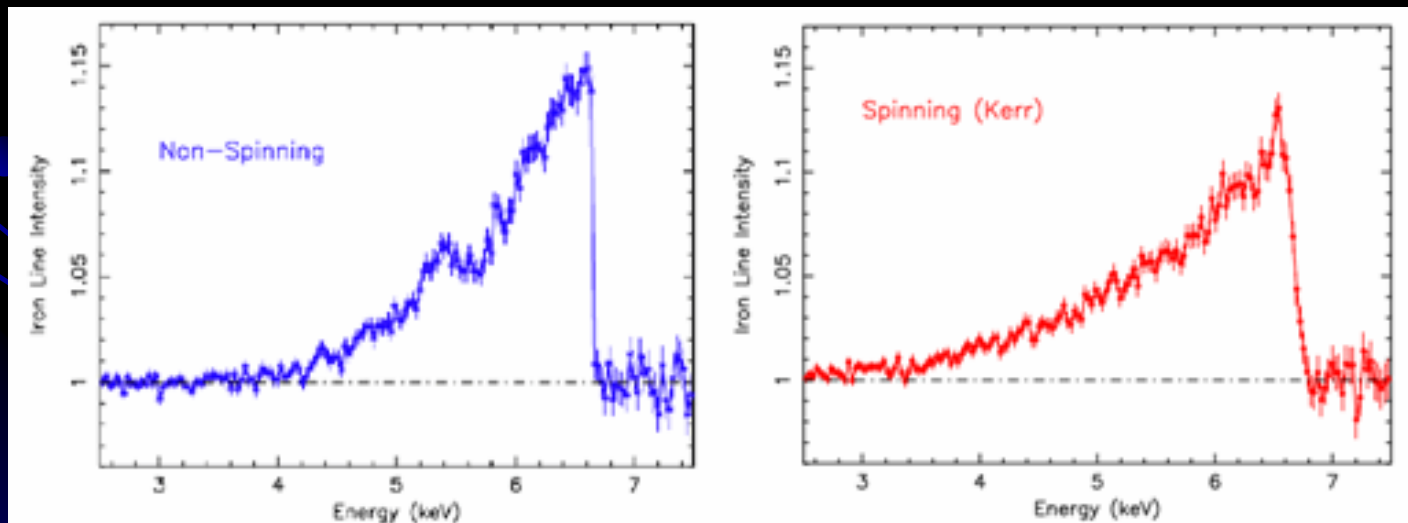
# Conclusions

- In order to achieve IXO science goals, the XMS detector needs to reject backgrounds
  - An anti-coincidence detector that uses a phonon collection system similar to CDMS can effectively reject backgrounds for XMS
  - Some R&D is needed for this XMS anti-coincidence detector
- 



# Black Holes

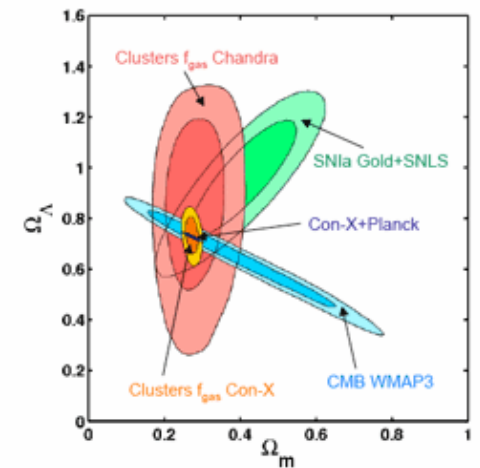
- Test General Relativity in strong-field gravity
- Measure black hole mass and spin
  - Study inner accretion disks through the broad iron fluorescence line in the x-ray spectrum of the black hole



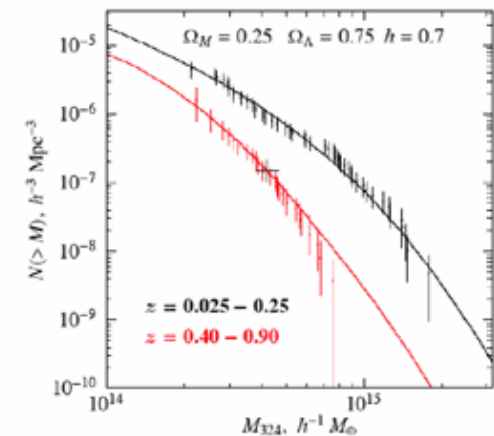
On the right we show a 300 ks Constellation-X simulation of the broad line expected for an AGN having the parameters measured for MCG -6-30-15 (a nearly maximally spinning black hole). The simulation on the left shows how different the iron line shape appears when the black hole is not spinning.

# Dark Energy

- Constraints of dark energy by looking at temperature and density profiles of galaxy clusters from x-ray emitting gas
  - Both “Geometric” & “Growth of Structure” measurements



The joint 68% and 95% contours on  $\Omega_m$  and  $\Omega_\Lambda$  from the current Chandra  $f_{\text{gas}}(z)$  data (red/pink). Also shown are the constraints from current SN Ia data (green; "gold" sample of Riess et al. 2004 combined with 1-year Supernova Legacy Survey data of Astier et al. 2006) and current CMB studies (light blue; WMAP 3-year; Spergel et al. 2007). The inner contours show the predicted constraints from the Constellation-X  $f_{\text{gas}}$  experiment (orange) and  $f_{\text{gas}}+\text{Planck}$  data (dark blue).



Current measurements of the evolving cluster mass function based on the Chandra observations of high- and low- $z$  clusters discovered in ROSAT surveys (Vikhlinin et al. 2007). The models are for the "concordance"  $\Lambda$ CDM cosmological model. These data (48 low- $z$  and 40 high- $z$  clusters) provide constraints on the dark energy equation of state parameter,  $\Delta\omega \sim \pm 0.12$ , when combined with WMAP.

# Previous X-ray Detector

- Suzaku
- X-ray Spectrometer (XRS)
  - XRS upper threshold was 12 keV
- Anti-coincidence detector readout ionization signal
  - XRS anti-co default trigger was 16 keV
  - XRS anti-co detector was 0.64 mm behind the XRS array plane